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Using the Contribution Analysis Approach to Evaluate Science Impact: A Case Study of the National Institute for Occupational Safety and Health

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Abstract

Interest from Congress, executive branch leadership, and various other stakeholders for greater accountability in government continues to gain momentum today with government-wide efforts. However, measuring the impact of research programs has proven particularly difficult. Cause and effect linkages between research findings and changes to morbidity and mortality are difficult to prove. To address this challenge, the National Institute for Occupational Safety and Health program evaluators used a modified version of contribution analysis (CA) to evaluate two research programs. CA proved to be a useful framework for assessing research impact, and both programs received valuable, actionable feedback. Although there is room to further refine our approach, this was a promising step toward moving beyond bibiliometrics to more robust assessment of research impact.

Keywords

government evaluation; impact evaluation; public health; case studies

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Greater accountability in government is of interest to Congress, executive branch leadership, and many other stakeholders. Evaluation and performance measurement continue to gain momentum today with government-wide efforts such as the Government Performance and Results Modernization Act of 2010, the Evidence-Based Policymaking Commission Act of 2016, and yearly updates to the Office of Management and Budget Circular A-11 Part 6. At the same time, federal agency spending is increasingly under budgetary constraints, also leading to greater emphasis on program evaluation. Federal agencies need to validate that their activities are directed toward the highest priorities of their stakeholders and demonstrate the impact of their work (American Evaluation Association, 2013). Federal research programs face unique difficulties showing the impact of their work. For example, the time it takes to move research from the basic to the applied end of the research

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continuum can often be lengthy (Maynard, Goldstein, & Nightingale, 2016). Moreover, the difficulties associated with measuring the impact of a research finding, particularly proving cause and effect associations, are significant (U.S. Government Accountability Office, 2013). While tools like bibliometrics and journal impact factors serve as mechanisms for measuring an individual's or organization's scholarly impact, they do little to demonstrate real-world outcomes (Agarwal et al., 2016). This article presents a case study of the sustainable, evidence-based approach one federal research organization is applying to evaluate the impact of its scientific research.

The National Institute for Occupational Safety and Health (NIOSH) generates new knowledge in the field of occupational safety and health and seeks to transfer that knowledge into practice. NIOSH is part of the Centers for Disease Control and Prevention (CDC), an operating division of the U.S. Department of Health and Human Services. NIOSH has been investing in evaluation for more than a decade. In response to NIOSH's 2004 Performance Assessment Rating Tool review, NIOSH commissioned the National Academies of Sciences, Engineering, and Medicine in 2005 to conduct peer reviews of eight of its largest research programs (Howard, 2009). To prepare for these reviews, NIOSH worked with the RAND Corporation to develop an Institute's logic model (Williams, Eiseman, Landree, & Adamson, 2009; Figure 1). The National Academies Framework Committee then utilized this logic model and added definitions for each of the components (Table 1), along with specific scoring criteria for relevance and for impact using a scale of 1–5 (Institute of Medicine and National Research Council, 2009).

In 2016, we, the evaluators at NIOSH, began to develop a new approach for conducting external impact evaluations of its research programs. Primary considerations for developing the new approach included lessons learned from the earlier eight reviews, advances in evaluation science, and the desire to sustain rigorous, independent program evaluations over time. These evaluations would also fulfill a Government Performance and Results Act (GPRA) requirement. In order to increase the likelihood of sustainability, we had to consider both the financial and staffing resources needed to commit to a program evaluation. Ultimately, we decided to refine the Institute's original program evaluation approach. The new approach includes key components of the previous approach such as an evidence package organized by occupational safety and health outcomes, program-specific review panels, and scoring criteria based on relevance and impact. At the same time, the process is now theory driven and more utilization focused. Furthermore, the new review approach balances rigor and independence with the financial costs of evaluation.

Method

Selecting Contribution Analysis (CA)

Evaluation science has advanced since NIOSH developed its first approach to reviewing its research programs in 2005. A recent literature review by Greenhalgh, Raftery, Hanney, and Glover (2016) found more than 20 models and frameworks for assessing research impact. We identified CA as a more refined approach (Mayne, 2001, 2011). We considered many frameworks including process tracing, contribution mapping, CDC science impact framework, and a synthesis of the Canadian and payback frameworks (CDC, 2017; Cohen et al., 2015; Kok & Schuit, 2012). We were also inspired by research impact time line infographics developed by the National Institutes of Health (2017) as a way to show the pathway from research to public health impact.

Although the purpose of impact evaluations is to determine whether a cause and effect relationship exists between the research program and the desired end outcome, it is difficult for research programs to demonstrate a definitive cause and effect relationship (Gertler, Martinez, Premand, Rawlings & Vermeersch, 2011). However, Mayne's (2001, 2011) CA approach emphasizes the importance of the program as an influencing factor in the theory of change. This is accomplished by assembling enough evidence to reduce uncertainty about the association, to reach "plausible association." One of the biggest strengths of CA is that it not only answers the question, "Did the program make a difference?" but it also helps programs understand how and why those impacts occurred. CA is well suited for programs like those at NIOSH, where multiple projects are undertaken with many partners, and the impacts occur over many years as a result of the convergence of efforts (Patton, 2012).

CA offered several appealing features that made it a good fit for NIOSH. It places emphasis on logic modeling and theories of change, which expands upon the logic modeling work done during and after NIOSH's first eight program reviews. Furthermore, it provides a structured pathway for compiling evidence and assembling it into a cohesive document, which is helpful for a government agency that works best within structure. One component of the earlier reviews that we wanted to further refine was the evidence packages. They were exhaustive inventories of work, loosely organized by logic model headers. CA provided a framework for developing more focused narratives that show the pathways NIOSH programs followed to move from basic to applied research, to move research into practice over time. Instead of having one logic model per evidence package to visually depict how the program overall moved from research to practice, we included one logic model for each chapter to show the pathways the program followed to move research into practice within a specific research topic (e.g., musculoskeletal disorders, methods development, infectious diseases, and sensors technologies).

One of the biggest advantages of CA is its flexibility around both the scope and the subject matter. NIOSH's program portfolio varies in terms of both the size of programs and the type of research. For example, the first two programs selected for review were substantially different. The Healthcare and Social Assistance (HCSA) Program is relatively large and includes a variety of basic and applied research on multiple health outcomes, while the Exposure Assessment (EXA) Program is much smaller and is exclusively devoted to laboratory research and methods development. Evaluating basic research has historically been especially challenging for NIOSH because it is often exploratory in nature and the pathway between research and practical use is longer and more complex than applied intervention research. The societal value of basic research can also be more challenging to demonstrate to policy makers (Bornmann, 2017).

Applying CA

Mayne (2011) offers three levels of implementation for CA. We chose the middle level, "contribution of direct influence," because Mayne describes it as the most realistic for research. This is a minimalist analysis that gathers evidence those areas of direct influence in the theory of change occurred and that the intervention was influential in the demonstrated results. In our application, this meant focusing on intermediate outcomes (such as an employer adopting a policy based on NIOSH research) rather than end outcomes (reductions in injuries, illnesses, and fatalities). We set out to demonstrate that expected intermediate outcomes were achieved and are likely to contribute to end outcomes in the long term. Potential for impact was a key concept in our implementation, since it often takes years to see changes in morbidity and mortality.

Mayne's (2011) framework was originally developed to evaluate social programs, so modifications are needed to evaluate research (Morton, 2015). Others have also made modifications (Dybdal, Nielsen, & Lemire, 2011). Our version of Mayne's (2011) framework (Figure 2) has peer review as an additional step at the end as a means to independently substantiate the program's contribution claim. Peer review has been and continues to be a critical component of research evaluation and is an adaptation that others have made to CA (Bornmann, 2017; Delahais & Toulemonde, 2012). This also served to carry forward an important piece of the National Academies review framework.

We also chose to place less emphasis on articulating assumptions and risks because they are fairly standard across NIOSH programs. The four categories of influence that assumptions and risks assigned to (control, direct influence, indirect influence, and no influence) map directly on to the NIOSH logic model. Outputs are under our control. We have direct or indirect influence on intermediate outcomes and little to no influence over end outcomes. The typical assumption of outputs is that they reach the right audience, and the information is timely, pertinent, and credible, whereas the risk is that the information does not reach the right people or does not meet their needs. For intermediate outcomes, the assumption is that partners are willing and able to take action, while the risk is that partners do not take action due to lack of leadership support, financial constraints, or shifting or competing priorities. For end outcomes, the assumption is that enough partners take action to reach a critical mass and effect change, while the risk is that not enough partners take action or that external forces counteract partner actions. The work of Morton (2015) was especially helpful in considering assumptions and risks of research.

While most of the steps in the framework were completed by the program with assistance from evaluators, the first step of Mayne's framework, "Set out the cause–effect issue to be addressed," was completed by the evaluators. This step answers foundational questions that set the stage for not only these two program evaluations but all subsequent ones as well. For the evaluation questions, we selected "Has the program made an important contribution to the observed intermediate outcomes? Is it likely to contribute to end outcomes in the future?" which aligns with our scoring criteria for impact. We set parameters for the programs about the level of detail required by setting page guidelines and criteria for what type of evidence could be included. For example, all intermediate outcomes had to be documented in some way, preferably in an official document, but e-mail records were also acceptable. We also considered other influencing factors that may affect research impact, including the economic recession in 2008 and its broad impacts on workers and employers, the efforts of other federal agencies, and NIOSH's partnership work in the National Occupational Research Agenda.

To start the evaluation, we worked with program management to identify and begin building what Mayne (2011) refers to as theory strands. In our application of this approach, each strand represents a different research topic or program goal. The number of strands varied from program to program. For instance, the HCSA Program evidence package included four strands, while the EXA Program had two strands. We worked with the two programs to create a logic model for each strand, moving from right (desired end outcome) to left (inputs). Since these reviews were retrospective in nature, the theory of change underlying the logic model already existed, but we helped to guide program managers to articulate the logic within the strand.

Figure 3 illustrates one of the logic models developed by the EXA Program for their evidence package. It depicts their work around sensors and direct reading instruments, which has an important, but indirect role in occupational safety and health. While changes in workplace policy, practice, and behavior were typical intermediate outcomes for more intervention-focused theory strands developed by the HCSA Program, this strand focused more on the commercialization and use of these technologies as intermediate outcomes. It is our hope that employers and workers will take action to make changes in workplaces if the data provided by these instruments suggest hazardous exposure levels, but it is beyond our direct influence. The logic models were retrospective and featured completed activities, outputs, and intermediate outcomes. However, in a few cases, we included items that were near completion and used dotted boxes and lines to indicate they were projections.

One limitation of CA, and theory-based evaluation in general, is a tendency to use overly simplistic theories that lead to superficial or incomplete knowledge (Dybdal et al., 2011; Lemire, Nielsen, & Dybdal, 2012). At the same time, complicated logic models can make CA unfeasible (Delahais & Toulemonde, 2012). Based on peer reviewer feedback in the previous program reviews, complicated, text-heavy logic models were not as useful as they might have been. Therefore, we aimed to develop logic models that provided sufficient detail about how the program contributed to impact, yet did not become bogged down in minutiae.

Each draft logic model then guided the development of the CA narrative. Each strand was a chapter in the program's evidence package, and each chapter was organized into the following sections: introduction, logic model, inputs, activities/outputs, transfer/translation, intermediate outcomes, end outcomes, alternative explanations, and future directions. These sections provided detailed evidence about each item in the model and its role in the strand.

For example, in the EXA Program evidence package, we illustrated one pathway in the logic model (Figure 3) by providing descriptions of the sensors developed by NIOSH, commercialized by manufacturers, and used appropriately in occupational settings to change workplace practices and reduce hazardous exposures. One such sensor, the continuous personal dust monitor (CPDM), detects hazardous coal mine dust in a miner's breathing space. Data are reported on a digital readout throughout the miner's shift and are also recorded in a database. The CPDM has been commercialized and its use in coal mines was mandated by the Mine Safety and Health Administration (MSHA) starting February 1, 2017. Early data from MSHA and anecdotal reports to NIOSH researchers indicate that miners are already using information from the CPDM to either move themselves to areas where dust levels are within safe limits or make ventilation adjustments to their workspaces (Mischler & Coughanour, 2017; NIOSH, 2016). Examining alternative explanations, we determined that while MSHA and mining employers were important partners, these workplace changes probably would not have been possible without NIOSH's research and engineering work on the CPDM, or at minimum would not have happened this soon. In this case, there was clear evidence of research translation, which we took as an indication that the assumptions were accurate and the risks did not come to pass.

In the HCSA evidence package, much of the focus was on the use of evidence-based recommendations made by NIOSH. These recommendations are primarily shared through pdf documents, which are advertised through social media, the NIOSH Science Blog, and other communication channels. We had varying levels of evidence of use. Downloads (and to a more limited extent, page views) helped affirm our assumptions that the information was reaching the intended audience, but is a very weak indicator of use. Citations of NIOSH recommendations by other organizations (such as other federal agencies and professional associations) indicate the information is seen as credible and useful. The strongest evidence, though, are unambiguous examples that the recommendations were adopted. When we were able to demonstrate implementation, we believed our assumptions were confirmed and the risks were minimized. Conversely, if we could not demonstrate that the recommendations were adopted, we concluded that while the pathway was still plausible, it was equally possible that one or more of the risks interfered. Understanding why uptake did not occur is ripe for future translation research or evaluation but was outside of this scope of this effort.

Although some other evaluators have used very structured processes like the Relevant Explanation Finder (Biggs, Farrell, Lawrence, & Johnson, 2014; Lemire et al., 2012) for CA, we chose to approach this more like a scientific report. For example, the activities/ outputs sections were written somewhat similar to a literature review of the program's research and qualitatively described the boxes and arrows in the logic model. This approach is keeping with the evidence packages developed during the earlier program reviews. Moreover, on a practical level, the program staff, rather than our evaluation team, did the bulk of the work and they were comfortable and proficient with this kind of scientific writing.

Information for the narrative was gathered through NIOSH records, interviews with intramural NIOSH researchers, and grantee final reports. NIOSH was unable to complete the administrative process required for federal agencies to systematically contact extramural grantees or other external stakeholders to seek input. That process typically takes 12–18 months and NIOSH had only 7 months to complete the evidence packages in order to meet GPRA reporting deadlines. However, the programs are in frequent contact with a variety of partners and were able to do secondary analysis of existing program records to help address this limitation (Heaton, 2008). Program staff also used search engines to find practice guidelines and other documents that used NIOSH research but are not typically indexed in scholarly databases as a means to move beyond bibliometrics (Sarli, Dubinsky, & Holmes, 2010). These kinds of documents are an important source of evidence of research impact on policy (Bornmann, 2017).

Previous users of CA have noted that the methodology does not specify how to operationalize alternative explanations, yet they are critical for gauging the strength of evidence for contribution (Delahais & Toulemonde, 2012; Dybdal et al., 2011; Lemire et al., 2012). In our evidence packages, we devoted a section of each chapter to articulating the work of other organizations on the research topic. For instance, around the same time that HCSA Program created a violence prevention training for nurses, a national nursing association launched a violence prevention social marketing campaign, which may have also influenced change. Alternative explanations were sometimes touched upon during our initial logic modeling sessions, but by and large, this information was gathered along with other evidence.

Like Dybal et al. (2011), we found that the steps of developing the theory of change and gathering evidence merged in application. Throughout the development of the narrative, the research programs went through several iterations of each logic model as evidence showed new intermediate outcomes or pathways or no evidence could be found to substantiate the initial hypothesized pathways. The evaluation team provided feedback on multiple drafts of each chapter, identifying places where claims needed to be better substantiated or more clearly articulated. Because our team is small and engaged in other evaluation and performance activities, our main role was to serve as a “critical friend,” while the programs did the bulk of the work (Rallis & Rossman, 2000).

Reviewer Report and Scoring

An independent review panel, assembled by an independent scientific, professional, and engineering support contractor, reviewed each program. A list of three to five potential panel chairs were submitted to the contractor by each program. Upon thorough vetting, for conflicts of interest, the contractor selected a review panel chair for each program. Each chair then worked with the contractor to assemble a panel that included 2–3 subject matter experts, an evaluation expert, and a translation science expert. Program evidence packages were sent to their respective panels 1 month in advance of a 1.5 day in-person panel meeting. On the first day, panel members received presentations from the NIOSH program manager and NIOSH scientists, followed by a question and answer session. On the second day, the chair and panelists held a closed-door session to discuss their thoughts and create a plan to develop a report.

Similar to NIOSH’s previous program reviews, the current reviews are focused on assessing programs’ relevance and impact. The peer reviewer’s role was to use their professional expertise to judge the strength of the contribution claim based on the evidence provided rather than to substantiate or disprove it. Each panelist provided an individual score from 1 to 5 for both relevance and impact using a scoring rubric provided by NIOSH. Relevance scores reflect the reviewer’s assessment of the program’s justification for conducting research related to the strands presented. Impact scores reflect the panelist’s assessment of the program’s ability to translate research into practice and achieve impact. The chairs were responsible for synthesizing all the comments from panelists together into a comprehensive report, as well as calculating the average scores for relevance and impact and adding the two average scores together to arrive at a program score out of 10. To close out the review, the panel, led by the chair, provided a brief presentation of their report to NIOSH followed by a brief question and answer session to gain additional clarification or explanation where needed. At the conclusion of each review, we work with program management to develop an overall response document to the panel reports, as well as a more specific implementation plan.

Discussion

Our application of CA was overall successful. Both programs received useful feedback from the review panels on program strengths and challenges, and NIOSH was able to meet the requirements of our GPRA performance measure. Although we did identify opportunities for improvements in both the evidence package and peer review, we found no fundamental flaws in our application of CA.

Using a theory of change and placing more emphasis on intermediate outcomes in the CA approach rather than assembling an exhaustive list of activities and focusing on end outcomes in prior reviews allowed panel members to provide more targeted, actionable recommendations. In contrast to our previous set of reviews, we narrowed the scope of each program review by choosing only those occupational safety and health topics within the program that both program management and NIOSH evaluators determined to be ready for impact evaluation. This allowed us to develop logic models with explanatory text to describe what pathways were used to get from inputs to intermediate outcomes. This resulted in more informed reviewers, asking more specific, pointed questions of the programs, and ultimately providing more specific recommendations.

It is also worth noting how well basic research fit into the CA approach, which historically has been very challenging for us. Evidence of intermediate outcomes surrounding basic research was quite different, focusing on the adoption of methods in laboratories and the use of sensors in the field rather than changes in workplace behavior or policy, but ultimately the framework was still applicable. The review panel for the EXA Program even commented on how they appreciated the CA framework and our use of logic models. The adaptability of CA is, in our eyes, its greatest strength.

The evaluation of these two programs also provided an opportunity to strengthen evaluation capacity at NIOSH and further build a culture of evaluation. While the logic model concepts of outputs and intermediate outcomes have been institutionalized at NIOSH, we still struggle with imparting to frontline scientists about the importance of measuring societal impact in addition to scholarly impact. Bibliometrics are one kind of intermediate outcome, but there are many others that are critical for understanding the real-world impact of NIOSH research. Scientists from across NIOSH either wrote or reviewed pieces of the evidence package, which provided opportunities to explain the purpose and value of this evaluation and impact evaluation more broadly.

One of our greatest challenges during this process was the amount of time required. As we were considering research impact frameworks and deciding our approach, feasibility was one of our key criteria. By using a more focused approach, we hoped to reduce the workload into something manageable for program management that would be sustainable over time. However, from our own experience and feedback from program staff, this was a much bigger undertaking than anticipated. Both programs completed their evidence packages in 7 months, but 8–10 would have been preferable. This supports Delahais and Toulemend's (2012) assertion that CA is more time-consuming than other types of theory-based evaluation.

In the future, we will organize chapters in the evidence packages by contribution stories that illustrate pathways in the logic model rather than by logic model header. For example, the activities, outputs, and intermediate outcomes related to preventing influenza transmission among health-care workers would be presented together rather than spread across several sections. Based on feedback from the peer reviewers and NIOSH program management, we believe this will further enhance the reviewer's ability to judge how well the evidence supports the contribution claim. We also continue to emphasize to peer review panels that we are implementing the middle level of CA, "contribution of direct claim." Intermediate outcomes, rather than end outcomes, are the basis of our evidence.

One limitation of our application of CA is that our evidence packages were perhaps too linear and did not fully acknowledge the unpredictability of science. Scientific progress is not always cumulative, and sometimes lines of research do not ultimately pay dividends. Serendipity can also play role in science that is difficult to articulate and substantiate in a theory of change. This is a broader challenge in measuring research impact, and not specific to CA, however (Bornmann, 2017). Another area that we can improve upon in future applications of CA is more direct evidence of adoption of NIOSH interventions. Both peer review panels commented on our overreliance of proxy measures such as downloads of guidance documents. We agree with this critique and are already taking steps to improve in this area and plan to include more case studies as part of the next program reviews. Our attitude all along has been in accordance with Greenhalgh et al. (2016) in that the perfect is the enemy of the good when it comes to measuring impact. We know we must go beyond proximal, short-term impacts, but it will take time and further building of evaluation capacity at NIOSH.

Conclusion

CA is a helpful framework for evaluating research impact and moving beyond bibliometrics and journal impact factors to a more comprehensive and robust range evidence of societal impact. As federal resources become increasingly constrained, the burden on federal science research agencies to demonstrate the impact of their work will continue to mount. Research agencies like NIOSH must develop and implement creative, rigorous, and cost-effective mechanisms to demonstrate the relevance and impact of their work.

As HCSA and EXA Programs are the first of NIOSH's programs to attempt this approach, its effectiveness in demonstrating program relevance and impact is still in its infancy. Over the next several years, as more NIOSH programs are externally evaluated and the CA approach is refined, the effectiveness and sustainability of this approach for evaluating occupational safety and health research programs can be more fully assessed and reported.

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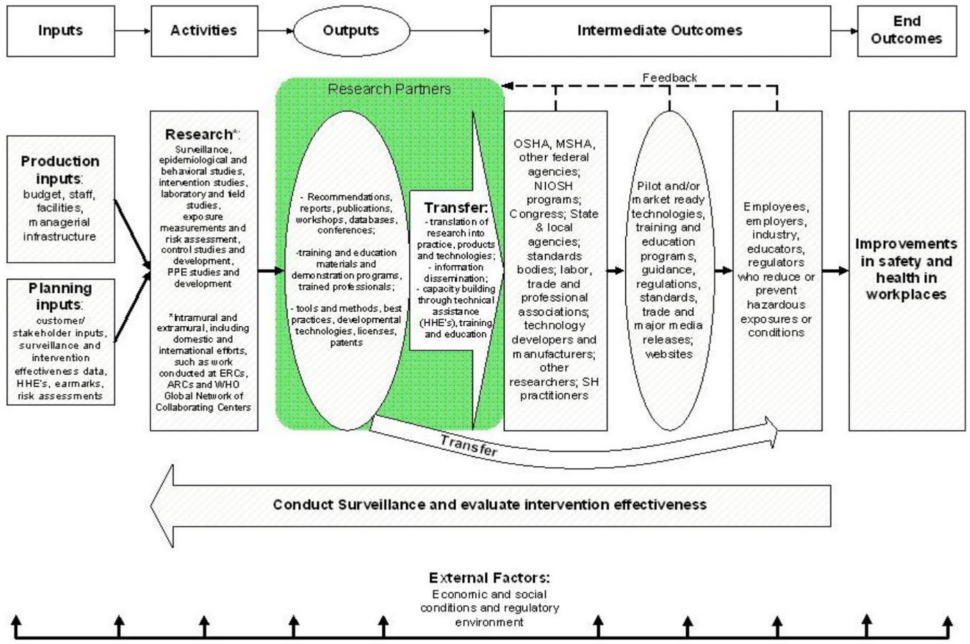

Figure 1.

National Institute for Occupational Safety and Health's logic model.

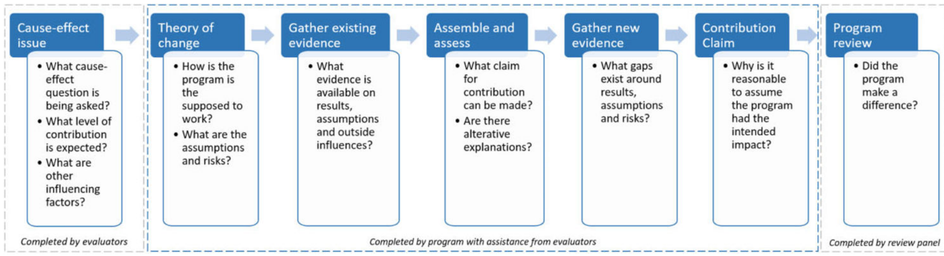

Figure 2.
National Institute for Occupational Safety and Health's application of contribution analysis.

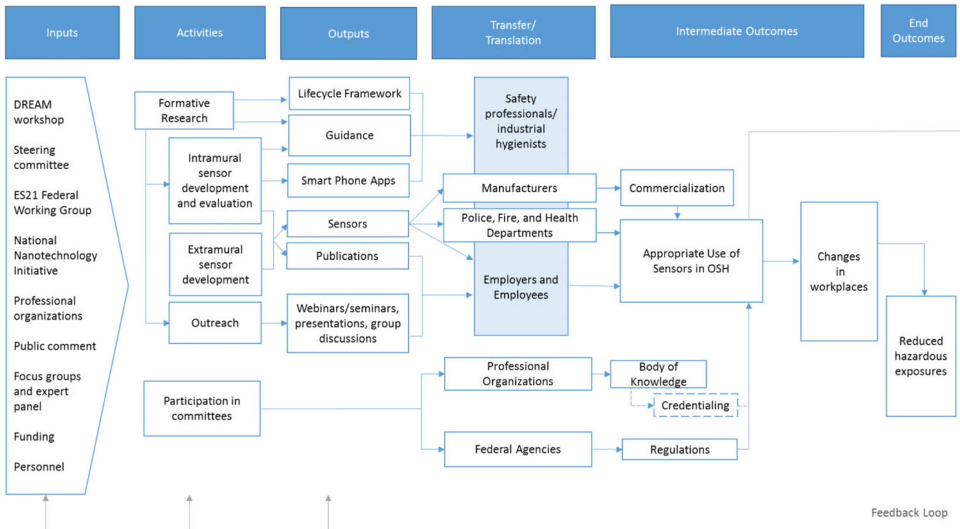

Figure 3.

Exposure Assessment Program—sensor technologies logic model.

Table 1

Logic Model Headings and Definitions.

Logic Model Headings	Definition	Examples
Inputs	Planning inputs: stakeholder input surveillance and intervention data, and risk assessments Production inputs: intramural and extramural funding, staffing, management structure, and physical facilities	Facilities Staff Surveillance data Research agenda Stakeholder input
Activities	Efforts and work of the program, staff grantees, and contractors	Surveillance Research Translation Service on committees
Outputs	Direct products of NIOSH programs that are logically related to the achievement of desirable and intended outcomes	Criteria documents Technologies Training tool kits
Intermediate outcomes	Actions by stakeholders in response to NIOSH products or efforts	Adoption of a NIOSH: Technology Training tool kit Recommendation
End outcomes	Improvements in safety and health in the workplace that can be attributed to NIOSH efforts	Reduction of occupational: Injuries Illnesses Deaths Hazardous exposures
External factors	Actions or forces beyond NIOSH's control with important bearing on moving research results into practice into the workplace	Regulations Industry actions

Note. NIOSH = National Institute for Occupational Safety and Health.